# DESCRIPTION
# OF THE
# SYSTEMS INTERACTION PROGRAM
# FOR
# SEISMICALLY-INDUCED EVENTS

DIABLO CANYON UNITS 1 AND 2

May 27, 1980

Pacific Gas and Electric Company

SYSTEMS INTERACTION PROGRAM

CHAPTER 1 - INTRODUCTION

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SYSTEMS INTERACTION PROGRAM

# CHAPTER 1 INTRODUCTION

## 1.1 PROGRAM OBJECTIVE

The System Interaction Program for Seismically-Induced Events is to be conducted for the purpose of further eliminating the possibility of detrimental seismically-induced interactions between safety related equipment and nonseismically qualified equipment at the Diablo Canyon Power Plant. Detrimental interactions are those that could conceivably compromise the function of safety related equipment. This program will establish confidence that when subjected to seismic events of seventy, up to and including the postulated 7.5M Hosgin event, all Diablo Canyon Nuclear Power Plant structures, systems and components important to safety shall not be prevented from carrying out their required safety junction by physical interaction with non-safety related structures, systems or components. Nor shall they lose the required redundancy to compensate for single failures because of such physical interactions.

For the purpose of this report a target item is a structure, system or component important to safety as defined in 10 CFR.50, Appendix A, General Design Criteria for Nuclear Power Plants; a source item is any structure, system or component which does not fall under this category. Henceforth, these will be referred to as target and source. In terms of relationship, a source is an item which affects a target.

The program will result in the identification and compilation of the following information:

a. Target Equipment to be evaluated for potential interactions with source equipment

b. Postulated failures

c. Postulated interactions

d. Analyses and resolutions to be handled in the field

e. Analyses and resolutions to be handled in the general office

f. Recommended plant modifications.

## 1.2 PROGRAM SCOPE

The porgram will include identification of target electrical, mechanical, fluid, pneumatic, and control equipment and components which are important to safety and which therefore must be evaluated for possible interactions with source equipment or components. A list of this required equipment will be prepared according to location in the existing plant fire zones. These fire zones are convenient spatial subdivisions.

The program will be implemented by the following activities:

A. Initial Office Activities

The First Task is the identification of all target equipment. All functions, systems, and components will be identified together with associated information such as operability requirements.

The Second Task is the identification of target equipment according to location in the existing plant fire zones, which provide convenient spatial subdivisions.

The Third Task is the preparation of detailed criteria.

Some of these criteria will be cast in a form suitable for use during the field walkdowns; others will be directed toward office evaluation and resolution.

Finally, a documentation data base, suitable for providing quality control for the entire systems interaction program, will be designed to ensure that all potential interactions are documented and resolved in a traceable and retrievable manner.

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### B. Field Walkdown Activities

1. Confirming Walkdown

   After the target components have been identified and located during the office evaluation phase, an inspection will be conducted of each fire area to ensure that the data base to be utilized during the walkdown is accurate and complete.

2. Interaction Walkdown

   A walkdown will be performed by an interdisciplinary team of experienced engineers. During the inspection, all possible interaction failure types will be postulated and recorded using established criteria.

3. Inter-Compartmental Walkdown

   An additional walkdown by the interdisciplinary team will then consider the effects of adjacent compartmental interaction.

### C. Technicnical Evaluation

When data from the field walkdown are obtained, technical evaluations will be performed on unacceptable conditions.

D. Modifications

Unacceptable conditions as noted from the field walkdowns and validated through technical evaluation may require design modification to the plant. Such modifications, when required will be implemented.

E. Independent Audit

An audit of the program will be conducted by the Quality Assurance Department.

F. Independent Review Board

A review board, independent of PGandE, will monitor the program progress and report its findings to the consultant, managing the Review Board. The managing consultant will then report those findings to the Manager, Nuclear Projects.

## 1.3 REPORT DESCRIPTION

This report discusses the Systems Interaction Program for seismically-induced events. Chapter 1 presents a brief introduction of the program. Chapter 2 presents the Organization and make up of the program teams. Chapter 3 is a discussion of the Methodology of the Interaction Program. Chapter 4 presents the Criteria used for the program and Chapter 5 is a detailed description of the program.

## 1.4 REFERENCES

1. "Seismic Evaluation for Postulated 7.5 M Hosgri Evaluation" Amended 60, FSAR, Diablo Canyon Units 1 and 2, Pacific Gas and Electric Company, October 1977.

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# SYSTEMS INTERACTION PROGRAM

## CHAPTER 2 - ORGANIZATION

### 2.1 GENERAL ORGANIZATION

The System Interaction program is administered by the Nuclear Projects Department under the direction of a project engineer. Personnel from varrious PG&E organizations are assigned to the project and take functional directions from the project engineer. Several consultants are used to supplement the PG&E organization and to provide specialized assistance. Figure 2-1 indicates the reporting relationships among consultants and PG&E personnel who fulfill key roles in the System Interaction program.

### 2.2 RESPONSIBILITIES

#### 2.2.1 Independent Review Board

The Independent Review Board (IRB) is responsible for reviewing any aspects of the System Interaction program without restriction. Results of reviews will be submitted to the managing consultant, who interfaces with the Manager, Nuclear Projects. The Independent Review Board is made up of well established, experienced individuals from the professional and academic nuclear community.

#### 2.2.2 Nuclear Projects Manager

The Nuclear Projects Manager is responsible for the overall coordination of the program between PG&E and the consultant retained to manage the Independent Review Board. He also coordinates with the Manager -Nuclear Generation, Manager - Station Construction, Engineering Chiefs, others for recommendations of the Systems Interaction Project Engineer.

### 2.2.3 Systems Interaction Project Engineer

The project engineer reports to the Manager, Nuclear Projects and has the direct responsibility for the System Interaction Program. His responsibilities include the following:

a. Writing the System Interaction Program description.

b. Coordinating the efforts of consultants who are preparing the program, preparing implementing procedures, determining program inspection and evaluation criteria, and reviewing resolutions proposed by the Interaction Team.

c. Providing functional and technical direction to the Interaction Team.

d. Reviewing and approving the resolutions proposed by the Interaction Team.

e. Preparing interim reports and the final program report.

f. Communicating the activities of the Interaction Team and the results of the program to the Manager, Nuclear Projects.

g. Providing overall administrative direction for the program.

h. Initiating plant modification design changes resulting from the conclusions of the System Interaction Program analysis and resolutions.

The Project Engineer will use consultants to recommend technical decisions, assist with Nuclear Steam Supply System special considerations, provide administrative assistance, recommend resolutions, and provide analysis as needed. All consultants except as noted will report to the project engineer.

### 2.2.4 Interaction Team

The team members are required to have considerable experience on Diablo Canyon in their area of assignment and have been involved with the Diablo Canyon Project design, construction, or startup/ operation. As PG&E acted as their own architect-engineer-constructor for the project, experienced inhouse individuals are readily available. PG&E has also employed specialized consultants, architect-engineers, and NSSS suppliers to supplement the inhouse experience.

a. The Interaction Team comprises the following discipline supervisors and their staffs:

   (1) Mechanical Systems

   (2) Piping Supports

   (3) Instrumentation and Control

   (4) Electrical

   (5) Civil/Structural

   (6) Heating, Ventilating, and Air Conditioning

   (7) Programs

   (8) Startup/Systems

b. The discipline supervisors are selected from the staff of PG&E departments or from outside consultants, and are under the technical direction of the Engineering Discipline Chief.

c. The engineering staffs are selected from PG&E's Engineering Department, General Construction Department, Quality Assurance Department, startup/operations, or from outside consultants.

d. The discipline supervisors are responsible to prepare the procedures in their respective disciplines for the System Interaction Program, supervise the execution of the procedure, and coordinate the preparation of postulated failures, postulated interactions, and recommended resolutions.

### 2.2.5 Discipline Supervisors

a. The discipline supervisors prepare the procedures in their respective disciplines for the System Interaction Program, supervise the execution of the procedure, and coordinate the preparation of postulated failures, postulated interactions, recommended resolutions, and design changes.

b. The discipline supervisors report functionally to the Systems Interaction Project Engineer and technically to the Discipline Chief.

### 2.2.6 Quality Assurance

The Director, Quality Assurance reports to the Vice President, Nuclear Generation. He is responsible for maintaining an adequate quality assurance program and reviewing and reporting upon its effectiveness. The Quality Assurance Director is organizationally independent of those departments directly involved in the System Interaction Program. He has the authority and organizational freedom to investigate any problems pertaining to code or safety related items or activities, and initiate action which results in solutions.

Quality Assurance verifies implementation of corrective action. Should there be a breach of any part of the quality assurance program or the technical or regulatory requirements wherein public health or safety could be involved, the Director, Quality Assurance, has the responsibility and authority to stop the work.

Quality Assurance occasionally performs technical audits of certain programs and will request technical assistance from other departments. For the System Interaction Program, an engineer from each engineering discipline has been furnished. These engineers are experienced on the Diablo Canyon Power Plant but are not directly involved with the System Interaction Project and will take functional direction from Quality Assurance for the duration of the review and audit activities pertaining to the System Interaction Program.

The Director, Quality Assurance also supervises the Records Management Section which is not involved with the review or audit function. The Records Management Section is responsible to maintain records for Diablo Canyon in accordance with Title 10 Code of Federal Regulations Part 50 Appendix B Criterion XVII. The RMS section will microfilm essential data, records, documents, and drawings associated with the System Interaction Program and will maintain a computerized index of the microfilmed documents.

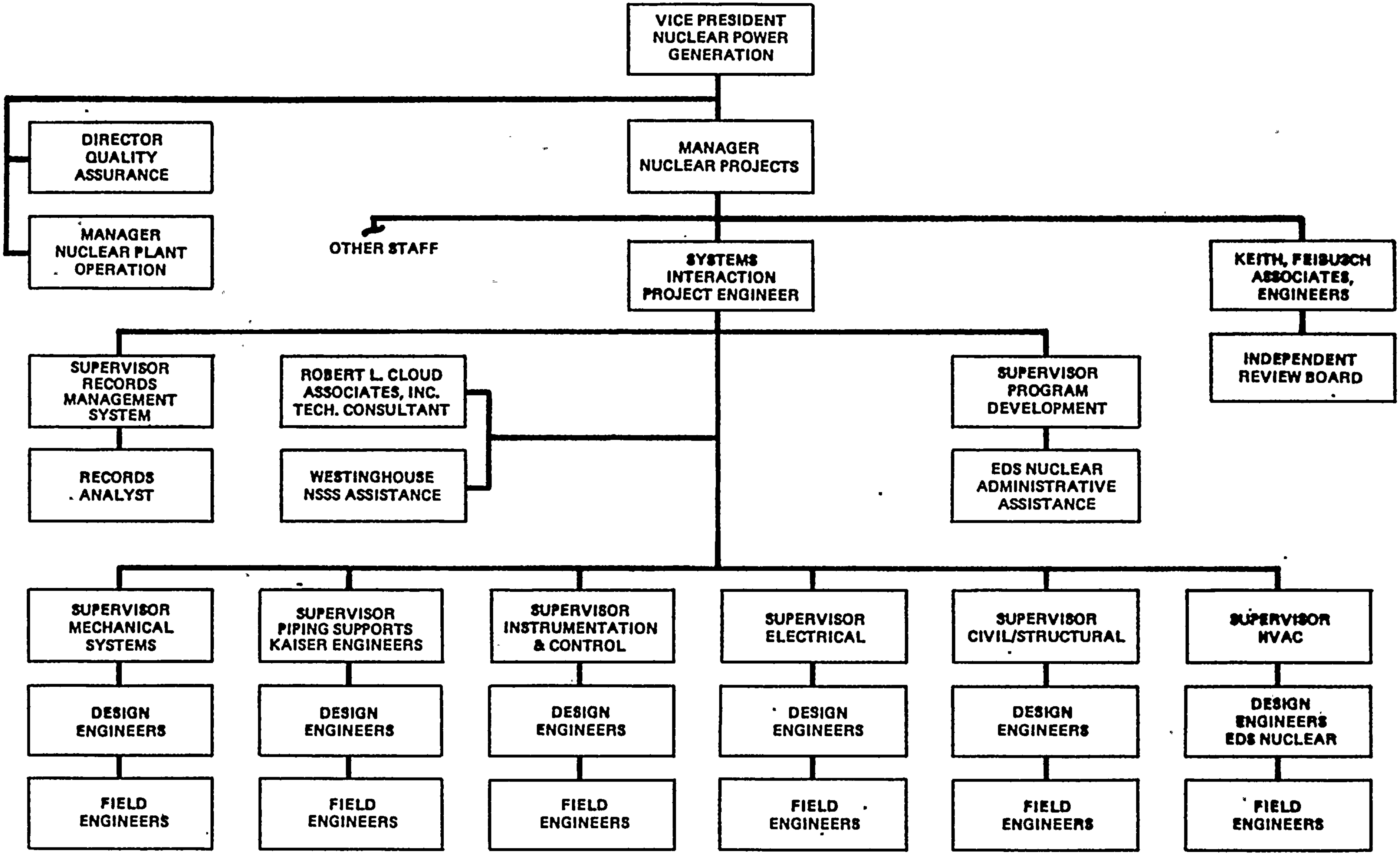


**FIGURE 2-1**
**SYSTEMS INTERACTION FUNCTIONAL ORGANIZATION**

SYSTEMS INTERACTION PROGRAM

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## CHAPTER 3 - METHODOLOGY

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# SYSTEMS INTERACTION PROGRAM
# CHAPTER 3 - METHODOLOGY

## 3.1 PURPOSE

This section describes the methodology and final documentation of the program.

## 3.2 GENERAL DESCRIPTION

### 3.2.1 Sequential Task Flow Diagram

The methodology is developed from the sequential set of tasks, or task flow diagram, as shown in Figure 3-1. Activities shown in Figure 3-1 and described in this report will be monitored by an Independent Review Board as described in Chapter 2.

### 3.2.2 Initial Office Activities

The first task of this program is the identification of all target structures, system or components. This will be accomplished by PG&E systems engineers in cooperation with systems engineers from the NSSS supplier. All individual target components will be listed. Most safety functions performed by more than one system and this redundancy will be maintained, even though it was originally incorporated as protection against such events as unforeseen system interactions. All functions, sytems, and components will be tabulated in matrix form, together with associated information such as operability requirements.

The second task is the preparation of a list of target equipment according to location in the existing plant fire zones, which provide convenient spatial subdivisions. These spatial subdivisions will also provide a means for addressing intercompartmental interactions during the plant walkdowns.

The third task is to prepare detailed working criteria for:

a. Postulation of failures for source equipment

b. Postulation of effects due to interactions with target equipment as a result of these failures.

c. Technical evaluation of potential interactions

d. Resolution of interactions. Some of these working criteria will be cast in a form suitable for use during the field walkdowns; others will be directed toward office evaluation and resolution.

These criteria are defined in Chapter 4 of this report.

Finally, a documentation data base, suitable for providing quality control for the entire systems interaction program, will be designed to ensure that all potential interactions are documented and resolved in a traceable and retrievable manner.

## 3.3 FIELD WALKDOWN ACTIVITIES

### 3.3.1 Confirming Walkdown

After the target components have been identified and located during the office evaluation phase, an inspection will be conducted of each fire area to ensure that the data base to be utilized during the walkdown is accurate and complete.

### 3.3.2 Interaction Walkdown

A walkdown will be performed by an interdisciplinary team of experienced engineers as described in Section 2. During the inspection, all possible interactions will be postulated for source equipment that might affect the target system to be protected, using the criteria as described in Chapter 4. Consideration will be given to local equipment arrangements and geometry, and the possible results of these failures. The interaction team, after identifying all possible interactions between source and target equipment, will utilize the established criteria to determine if these interactions are credible. Once the field system evaluation has been completed the following information will be documented.

a. Location of the potential interaction

b. Components and systems involved

c. Working criteria section used for the evaluation (which includes the type of interaction)

d. Recommendation of the interaction team. This may take the form of one of the following:

   (1) Finding whether or not an interaction occurs

   (2) Determine that, if interaction does occur, no safety function is impaired

   (3) Recommendation that a physical modification be designed and installed

   (4) Recommendation for further evaluation.

The Interaction Team will consider relevant failures to non-essential systems (e.g., loss of electricity and pressure) which may have an effect on the operation of target equipment.

When the Interaction Team enters a given fire zone, color coded system drawings will be used as maps or charts to follow all systems that require protection. As each item in the system and its environment are inspected, it will be checked off the master list or matrix.

During the plant walkdown, each item of equipment on the list to be evaluated for interaction will be inspected by the Interaction Team. Each unit of source equipment in the vicinity of the item will be considered to fail by any or all of the specific mechanisms in combination listed in the criteria (Chapter 4). When failure has been postualted, it will be possible during the inspection or, afterwards by offsite analyses, to determine interactions with the target equipment. All such interactions will be listed and evaluated using the established criteria as described in Chapter 4.

### 3.3.3 Intercompartmental Walkdown

The third walkdown by the interdisciplinary team will consider the effects of intercompartmental interactions. All possible intercompartmental interactions will be identified and relevant data such as color coded system drawings, and location and relevant numerical data will be documented. The walkdown team will physically inspect all adjacent compartments that may have interaction effects. Items such as flooding, electrical, pressure, and dynamic effects will be considered. Further interaction effects that may be determined from evaluation of the data base information may require a second intercompartmental walkdown.

## 3.4 TECHNICAL EVALUATION

As the data from the field walkdowns are obtained, office-based technical evaulations will be performed on unacceptable conditions noted in the field. Analyses, testing, and historical experience, when applicable, will be used to determine if the field-noted unacceptable condition is valid based on previously established criteria. If these office techniques demonstrate adequacy, no further activity (except documentation) will be required. If it is judged that the interaction condition is not correctable by technical evaluation techniques, a correction will be accomplsihed by design modification or a change in their operating modifications.

## 3.5 MODIFICATIONS

As potentially unacceptable conditions are noted in the field and evaluated to determine whetheror not the condition is significant, engineering modifications may be required. Depending on the type of modification required and the provisions of applicable QA requirements,

the design will be accomplished either in the field or in the office. Analyses or tests used as the design bases will be as described in Chapter 4. All design, analyses, and construction work will comply with project quality assurance and quality control requirements (as defined in Chapter 17 of the FSAR and corporate quality assurance manuals).

After required modifications have been completed, the systems modified will be checked in the field by the Interaction Team to assure that the modifications themselves have not resulted in unacceptable interaction conditions. Any unacceptable conditions will be resolved in accordance with the criteria of this manual.

## 3.6 INDEPENDENT AUDIT

The corporate Quality Assurance Department will direct a technical audit of the program. The independent audit team will include engineers knowledgable of Diablo Canyon (not presently involved with the System Interaction Program) from each of the engineering disciplines.

This team of engineers is responsible for the following:

a. Perform a sampling walkdown of representative compartments and their related intercompartmental interaction

b. Perform an audit of the previous intercompartmental walkdowns

c. Perform, on a sampling basis, separate analyses to verify that previous analyses were correct

d. Review program documents

e. Review completed modifications.

## 3.7 INDEPENDENT REVIEW BOARD

A review board independent of PG&E, as described in Section 2, will conduct a review of the program, which includes Systems Interaction walkdowns and a monitoring of the program's progress.

The independent review team will report its findings to the consultant, managing the Review Board. The managing consultant will then report those findings to the manager of Nuclear Projects.

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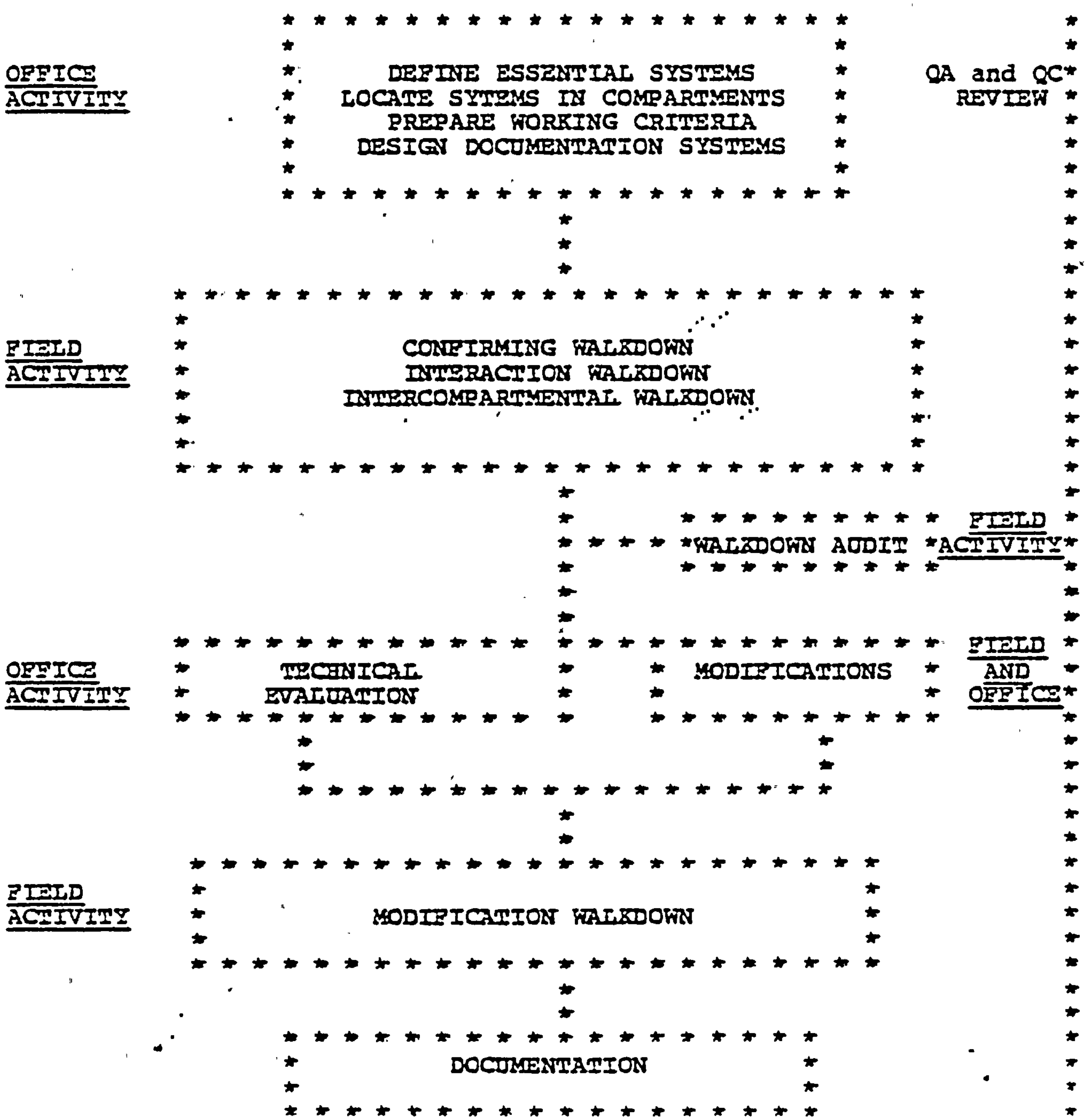
NUCLEAR PROJECT DEPARTMENT

Figure
3-1

**SEQUENTIAL TASK FLOW DIAGRAM**
**SEISMIC SYSTEMS**
**INTERACTION PROGRAM DESCRIPTION**



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SYSTEMS INTERACTION PROGRAM

## CHAPTER 4 - CRITERIA

### 4.0 CRITERIA

The following discussion delineates the criteria employed in the Diablo Canyon Nuclear Power Plant Systems Interaction Program for Seismically-Induced Events. It is organized along the lines of the program itself in that it proceeds from a fundamental guiding principle through identification of potential targets, sources, and interactions to evaluation and resolution of identified problems.

### 4.1 FUNDAMENTAL CRITERION

When subjected to seismic events of severity up to and including the postulated 7.5M HOSGRI event, the program will demonstrate that the capability of all Diablo Canyon Nuclear Power Plant structures, systems, and components important to safety shall not be prevented from carrying out their required safety function by physical interaction with non-safety related structures, systems, or components. Nor shall they lose the required redundancy to compensate for single failures because of such physical interaction.

The preceding paragraph embodies the entire spirit and intent of this program. Several clarifications follow to aid in understanding.

Seismically induced physical interactions include any and all credible failures or adverse behavior of non-safety related structures, systems, or components. The credibility will be based on conservative technical judgement of experienced engineers. In the identification stage of the program the instructions are to identify any doubtful or controversial cases for detailed evaluation.

Seismic events are considered to include both strong ground motion and tsunami as well as potential for full or partial loss of offsite power.

Interaction between two safety related items which has been qualified to withstand the postulated 7.5M HOSGRI earthquake is not deemed credible and is therefore not explicitly part of the program. If, however, in the course of the program, some design oversight or mistake of this type is observed, it will be evaluated and corrected as any other potential interaction.

Interactions which may be caused by other than seismic effects on non-safety related structures, systems, and components, such as human errors have been and are being investigated in other studies and are not explicitly included in the Systems Interaction Program for Seismically-Induced Events.

## 4.2 TARGET CRITERIA

The initial step in the program is the identification of potential targets. As defined in Chapter 1, any structure, system, or component important to safety is considered as a potential target and thereby may be susceptible to any detrimental effects of seismically induced behavior of nearby non-safety related structures, systems, or components.

## 4.3 SOURCE CRITERIA

Sources of detrimental interactions are any non-safety related structures, systems, or components which, by their proximity to safety-related structures, systems, or components and the absence of defensible seismic qualification, may physically interact through mechanical, electrical, or fluid means to degrade the plant safety features. Sources are considered singly and in credible combination with other sources.

Structures, systems, and components important to safety are not sources by virtue of their seismic qualification except that they may become sources as a result of interactions in chain-reaction with other sources. Such secondary sources are identified, evaluated, and resolved in the same manner as any others.

## 4.4 INTERACTION CRITERIA

An interaction is identified whenever the seismically induced behavior of a source could lead to detrimental physical effects on a nearby target. Pairings of targets and single or multiple sources are based on physical proximity or direct system connection. Then an assessment is made of the possible seismic behavior of the sources. An interaction is not identified by the field walkdown team i it can be established by cursory inspection that no credible failure mode can be induced in the sources by earthquakes up to and including the postulated 7.5M HOSGRI event which violate the fundamental criterion.

Instructions to the walkdown team are to identify doubtful cases for further evaluation. In general, interactions identified will be in one or more of the following categories:

a. Contact between a source and a target that would compromise operability of the target.

b. Fluid leakage from one or more sources that would negatively modify the environment of the target component.

c. Contact between a missile generated by a source and a target that would compromise the pressure boundary of the target component.

d. Contact between a missile generated by a source and a target that would compromise operability of the target component.

e. Secondary or chain interaction caused by any of the above interactions.

The following criteria provide guidance both to the walkdown team and to subsequent engineering teams for evaluation of the credibility of hypothetical interactions and their effects.

## 4.5 EVALUATION CRITERIA

The evaluation of seismically induced systems interactions and their effects on plant safety rests heavily on qualified engineering judgement. It is judgement which permits such a program to be accomplished since without some limits based on credibility or probability, the program would expand to an impossible magnitude. The following criteria supplement and exemplify the judgement element of this program. They do not replace the need for qualified engineers with design and operational experience to perform the evaluation, nor were they so intended. As discussed in Chapter 2, reliance is placed on assigned engineers in various relevant disciplines to apply their knowledge and experience in sorting the problems from the flights of fancy. These engineers were given the following criteria as guidelines to benchmark their evaluation. They were instructed not to be narrow in interpretation.

### 4.5.1 Evaluation of Sources

Potential sources are evaluated as part of the program to determine if seismic events can credibly lead to detrimental interaction with safety related structures, systems, and components. Following are three possible outcomes of this evaluation:

a. Seismic events will not lead to interaction because of defensible seismic qualification of the sources by analysis, test, or experience with the same or similar items.

b. Seismic events may lead to damage or failure of the sources, but the credible failure modes are no threat to the safety function of the target.

c. Seismic events may lead to a credible failure mode of the source which has the potential to cause adverse interaction.

The following criteria provide minimum guidance for evaluation of sources. They are tabulated by discipline with the generic code listing used in the program data base for convenience.

4.5.1.1 Structural Source Evaluation

In evaluation of non-safety related structures, certain types of "failure" or adverse seismically induced bevavior must be considered. Each of these types must, as a minimum, be consciously addressed for a situation where a structural source could possibly interact with a target. Most of these can be eliminated by inspection especially since nearly all structure housing safety related equipment has been seismically qualified. The remainder usually require some analytical evaluation. The structural failure modes include:

CF1 - Deflection of structural element exceeds the clearance between it and the "target" and may cause impact damaging the "target." No interaction is probable if the clearance is at least 1" greater than the calculation deflection.

Upper bound estimate $\Delta = \frac{L^2}{20d}$ [1]

(where $\Delta$ is the deflection in inches, L is the span in feet and d is the depth in inches) may be used in lieu of calculated deflection.

[1] Ref.: ALSc Amount of steel construction number and deflection coefficients.

CF2 - Failure of anchorage to concrete structure [2)]

CF3 - Failure of bolted connection between steel members [2)]

CF4 - Failure of structural steel member [2)]

CF5 - Unusual situation not otherwise covered

### 4.5.1.2 Mechanical Source Evaluation

The following is a set of failure modes for mechanical equipment and piping systems which must be considered when evaluating potential sources in these categories.

MF1 - Overturning is not considered where the distance, as measured from the base to the center of gravity is small compared to the base width. The criterion specified allows for overturning to be neglected when the inertial load applied at the center of gravity is less than .5g. This follows from the case of a cube which requires, to a first approximation, 1g to overturn. In this example, the CG distance is 1/2 the base width. Further conservatism is obtained because most mechanical equipment is held down by bolting, brackets, etc.

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[2)] These failure criteria apply to structural elements that could not be seimically qualified under this program.

MF2 - Failure of valve upperstructure to valve body junctions is assumed for the following cases:

a) All motor and air operated valves
b) All gear-operated valves with upperstructure lengths greater than 12".
c) All handwheel - operated valves with upperstructure masses greater than the body/bonnet mass.

A sizable number of valves with heavy upperstructures must be anticipated. Many of these had to be specially qualified for Class I service even though not classified as Class I.

Evaluations are performed for situations in which valves with significant upperstructures could violate the fundamental criterion if they fail structurally.

All power operated valve upperstructures are assumed to fail, although qualification by similarity to Class I valves can be applied in some cases. Upperstructure failure of some gear and handwheel-operated valves is assumed, although the number of cases considered should be small and any reanalysis should verify the structural adequacy of the as-installed configuration.

MF3 - Deflection at top of tanks and vessels per foot of tank height due to shell buckling of tank walls for the following cases:

a) Fluid inertial loads. Applies to all tanks of total mass greater than 100 lb. with shell thickness 1/2" or less.
b) Vacuum loads. Applies to all atmospheric pressure tanks larger than 500 gallon capacity.

Two causes of failures of low pressure storage tanks other than overturning (covered in MF1) have been observed in actual earthquakes: One cause is excessive load due to the sloshing weight of the contained liquids. The other cause is shell buckling failures due to formation of a vacuum at the tank roof as fluid sloshes and blocks the vent. These failures are historically observed to be restricted to tanks of relatively thin walls.

MF4 - Support failure for vessels of total mass greater than 100 lb. resulting in toppling of the structure and loss of fluid for the following cases:

a) All vessels supported on legs.
b) All vessels supported on saddles of 1/2" thickness or less.

Tanks are supported in a variety of ways, typically on legs, cylindrical skirts or saddles. Whereas shell buckling (Failure MF3) results in tank deflection, support failure could violate the fundamental criterion by allowing tanks to topple. Support failure is restricted to thin section skirts or saddles and to all leg supports. Vessels with significant amounts of attached piping which contributes to vessel stability is assumed to topple. Anchor bolting integrity is generally not compromised, however suspect configurations are treated as special situations, Criterion MF6.

MF5 - Pump support failure for all non-bedplate mounted pumps, resulting in displacement of the pump and/or generation of missiles.

This failure mode is listed for completeness. Since operability of Class II pumps is not an issue, the concern is for a pump which may break free from its anchorage. In general, little difficulty is expected in this area, as most pump assemblies are securely mounted to bedplates.

Pump support bolting are assumed adequate or treated as a special situation, Criterion MF6. All non-bedplate mounted pump supports, such as pedestals, cases, brackets, etc. are assumed to fail. Toppling of pumps does not occur because of the added stability contribution of the attached piping, although motor drivers will topple if support failure is postulated. An evaluation is made as to the possible consequences of pump displacements due to support failure and to the possible subsequent generation of,missiles.

MF6 - Extraordinary or unusual situations not otherwise covered.

In addition to the above failures, complete loss of power and control has been postulated in the systems study in which vital equipment has been identified. Postulated failures of other miscellaneous mechanical equipment are treated as a special situation.

### 4.5.1.3 Electrical Source Evaluation

Eight categories of failure type must be considered with regard to seismic effects on electrical sources (equipment and cabling). They are discussed briefly in the following section.

EFI - Overturning of cabinets, transformers, switchgear or other unsupported equipment where the center of gravity location as measured from the base is longer than the base width in all directions.

The same considerations discussed in regard to overturning of mechanical equipment apply to electrical equipment, i.e. overturning is assumed for cases where the distance to the center of gravity is significant compared to the base width.

EF2 - Support failure resulting in toppling of the structure and/or generation of missiles for all non-skid mounted electrical equipment greater than 100 lb. total mass.

Support Failures are assumed for all non-skid mounted electrical equipment greater than 100 lb. total mass. Qualification of such equipment by similarity to Class I equipment can be accomplished in many cases.

EF3 - Failure of equipment body for cases where extended unsupported structures greater than 24" in length are present.

Component structural failures are assumed for extended structures such as transformer bus insulators, switchgear, etc. Few cases of this type are expected, but this failure mode is included for completeness.

EF4 - Extraordinary or unusual situations not otherwise covered related to electrical equipment use this code in the data base. This is the category where the observations in the field bring to light interactions other than the mandatory generic types above.

BF1 - Failure of supports and collapse of cable trays that do not have vertical supports with a minimum spacing of eight (8) feet. Cables are not assumed to fail on the basis of historical experience within the PG&E system and elsewhere.

All cable trays at Diablo Canyon are designed and supported according to the requirements listed in a PG&E Drawing. In particular, vertical supports are required every 8 feet. This requirement very conservatively requires that a failure of vertical support be assumed if the specified spacing requirements are not met. If the spacing requirements are met, the support is very conservative and no failure need be assumed. Conduits are, in general, Class I components and therefore are assumed to fail. Any postulated failures of Class II conduit is treated as a special situation, criterion RF4.

RF2 - Longitudinal displacement (in direction of tray) equal to 5% of the length of the vertical support for all cable trays that do not have one longitudinal support every 20 feet.

The support standard provides for longitudinal support spacing of 20 feet. This is a conservative requirement, and when followed will support the trays adequately in the longitudinal direction. This criterion will conservatively account for possible interactions due to longitudinal motion of cable trays. The most widely used longitudinal support is a rigidly welded 4 x 4 x3/8 in. angle iron.

RF3 - Lateral displacement (perpendicular to direction of tray) equal to 5% of the length of the vertical support for all cable trays with support systems that:

a) have no lateral bracing

b) exceed the maximum length requirements specified

It is unnecessary to consider lateral displacement of the cable trays for those trays with suitably spaced supports that are laterally braced, which covers the preponderance of trays in the plant. If lateral bracing is absent or support spacing or support lengths do not satisfy requirements listed in the table, then a conservative lateral displacement must be considered. The allowable strut lengths are based on 50 #/ft. of cable, 1.5 g floor acceleration, and initial yielding of the supports, using specified properties.

RF4 - Extraordinary or unusual situations with raceways not otherwise covered.

Unusual conduit or cable support failures and cases where cable severence appears possible due to seismic effects are examples of special situations requiring further investigation.

4.5.1.4 <u>Heating, Ventilating and Air Conditioning (HVAC) Source Evaluation</u>

Five generic failure mode categories are considered for HVAC sources. The following is a brief discussion of each of these categories.

HF1 - Excessive swaying of ducts not laterally supported in compliance with the PG&E specification. Pacific Gas and Electric Company Specification "Furnishing and Installing of General Ventilation Systems in Auxiliary, Turbine-Generator and Containment Building for Unit 1 - Diablo Canyon Site" states:

Bracing: All ducts shall be adequately braced to structure to prevent horizontal movement.

Seismic duct bracings shall be located as indicated on the drawings. Where seismic duct bracing occurs, bracing may be considered as a duct hanger. Sway bracing shall be provided if horizontal movement is still possible after duct hangers and seismic duct bracings have been installed.

Ducts at the Diablo Canyon Plant laterally supported in compliance with the above are not subject to lateral deflection and will not act as a source of interaction in this manner.

HF2 - Failure of duct supports.

A PG&E Specification sets the standard for duct material, thickness and support capacity. A Table in the Specification gives the design accelerations for Class I ducts. Engineering analysis has shown that no over-stress of Class II ducts installed in compliance with the specification occurs under Class I loads. The only method by which a Class II duct may act as a source would be if it is impacted upon with a load sufficient to cause a shear failure. Shear failure is evaluated on a generic basis comparing capacity with envelop loads.

Deviations from the PG&E specification are acceptable without assuming failure provided the following design criteria are complied with and that components installed have a structural strength equal to or greater than that specified.

1. Duct suspension supports, including surface-mounted supports, rods, straps, and angles must be of adequate strength to support a minimum weight equal to ten times the actual weight of the supported metal. Anchor bolts and power-driven fasteners shall comply with standards set forth by the International Conference of Building Officials, 50 South Los Robles, Pasadena, California.

2. For steel, the maximum predicted stress is less than 22,000 psi used. For concrete, a strength of 3,000 psi is used.

HF3 - Failure of component support structure.

Mechanical equipment is generally supported by angles, channels or unistrut. Failure of the support structure may allow tipping, falling, sliding or overturning of the component. Stress analysis will be conducted on a case by case basis when and if required. This approach is taken due to the fact that much of the HVAC equipment is located in areas where few interactions are anticipated. Allowable stress is taken as the published material yield strength.

HF4 - Failure of component anchorage.

Anchorage failure is similar to support structure failure and the same logic is employed. Manufacturer's standards for shear and pullout capacity are not to be exceeded without assuming failures.

HF5 - Extraordinary or unusual situation as regards HVAC sources not otherwise covered.

During the walkdown effort, or unusual situations will undoubtedly arise. Resolutions of special situations will be conducted as necessary. Stress analysis will be used as required.

4.5.1.5 Piping System Source Evaluation

The following evaluation criteria are a guide for establishing whether failure need be assumed for unqualified piping or equipment. Nine failure mode categories must be considered. These are each discussed separately. Then a discussion is provided of criteria for use when analysis is done to evaluate the potential for failure.

PF1 - Guillotine or axial-type breaks are assumed as follows:

a) Threaded or mechanically coupled pipe less than 4"NPS: see criteria PF3 thru PF6.

b) Threaded or mechanically coupled pipe equal to or greater than 4" NPS: assume quillotine type breaks at all threaded or mechanically coupled joints.

c) Welded, brazed or soldered pipe: see criteria PF3 thru PF6.

Threaded or mechanically coupled pipe is more susceptible to seismic failure than welded pipe. Threaded or mechanically coupled pipe cannot accept the same level of deformation that welded pipe can. Threaded joints have less ductility than welded joints, especially in the larger pipe sizes (4" NPS and larger).

In the smaller pipe sizes, the relatively heavier fittings coupled with the greater flexibility of smaller diameter pipe eliminates the need to evaluate for complete severance. As a pipe bends, the strain in the wall will be directly proportional to the pipe diameter for a give deflection. For this reason small pipe is much more flexible. In addition, the inertial force is much less relative to the cross-sectional area than in larger pipe.

PF2 - Bolted flange separation is assumed due to flange bolt strain resulting in fluid leakage at:

a) Fixed locations such as pipe restraints and equipment nozzles.

b) Flange locations which deflect excessively: see criteria PF5.

Excessive deformation or seismic loads could cause flange bolts to stretch. However, relatively small permanent strain in the flange bolt can permit a disproportionately large lateral displacement of the piping system. It is therefore most likely that a properly designed flanged joint would actually separate, but since the actual bolt preload is difficult to determine, flange separation is assumed.

PF3 - Failure of fixed-end rod type or U-bolt pipe supports is assumed due to lateral displacement of piping systems that do not have lateral support in accordance with the spacing requirements.

Rod hangers of piping systems were reported to have failed on certain heavy power piping in the Great Alaska Earthquake. The rod hangers that failed were short fixed-end threaded hangers that concentrated the strain in the fixed end and broke. (Incidentally, the hangers broke, but the piping did not.) Therefore, it is reasonable to simply verify that the rod hangers provide the requisite flexibility or that the pipe is well anchored. Bending moments at the fixed end can become high unless adequate lateral support is provided. The maximum support spacings specified provide such restraint to preclude high loads in the thread area.

PF4 - Failure of vertical supports (rods, spring hangers, clamps, U-bolts, etc.) is assumed for piping support systems that do not meet the pipe support spacing requirements.

This category is included to ensure areview is made of piping for adequate vertical support to handle vertical seismic stresses. An evaluation is made that considers adverse consequences to the piping for all systems that do not meet the ANSI B31.1 spacing criteria.

PF5 - Lateral displacement of pipe is assumed in the amount given in Table 4-5-2 for pipe with lateral support that does not meet the spacing requirements.

It is not unusual for nonseismic piping to be adequately designed and supported for deadweight and thermal effects, but to have little resistance to lateral loads which can be imposed by an earthquake. In an earthquake the piping can, therefore, undergo large swaying or lateral motions. In fact these motions historically have not caused the pipe to fail, but for the present program it is reasonable to consider the possibility of interaction with safe shutdown systems. The entire pipe span will be assumed to deflect by the amount shown in Table 4-5-2 concurrent with all other probably pipe motions.

The pipe spans specified are based on the vertical hanger spacing requirements of ANSI B31.1. This spacing provides a conservative limitation on lateral pipe movement as the deflection is derived from inertial loads only with no contribution from deadweight loads. Very long runs of laterally unrestrained pipe will be treated as an unusual situation, Criterion PF9.

PF6 - Lateral displacement is assumed at pipe in the amount given in Table 4-5-2 for pipe spans with concentrated masses (except flanges and flow elements). This applies if both of the following conditions are met:

a) Concentrated mass located within the middle 50% of the span.

b) Concentrated mass greater than equivalent pipe, 3 diameters in length.

c) Span length does not exceed amount shown in Table Concentrated masses such as valves located within a pipe span lower the span resonant frequencies and raise the resultant deflections. Additional restraints are usually located near concentrated masses to limit deflection. Concentrated mass situations where the span length exceeds the amount specified will be treated as a special situation, Criteria PF9.

PF7 - Longitudinal displacement of pipe is assumed in the amount given in Table 4-1-2 for pipe with less than one longitudinal support for each four maximum support spacing distances specified for lateral deflection.

Longitudinal displacement is limited by vertical pipe runs, U-bolts around the pipe and building interferences. Such displacements are generally present for long horizontal runs of pipe supported by rod and spring hangers or by struts and brackets where U-bolts are not utilized. Properly installed U-bolts constitute adequate longitudinal support.

PF8 - Leakage area equal to one flow area is assumed to develop gradually, at all threaded or mechanically coupled joints (except flanges) of pipe 4" NPS and larger.

Leakage is assumed to occur, although previous analysis have been performed regarding the capability of the plant to cope with a flooding situation. Sudden pipe breaks that result in pipe whip are not expected. Leakage will be postulated to occur at threaded or mechanically coupled joints only on the basis of historical experience.

PF9 - Extraordinary or unusual piping situations not otherwise covered.

It is expected that the experienced engineers carrying out this program will identify some cases which do not fit the other generic categories or represent combinations of failure modes. Such cases are to be evaluated as the circumstances dictate.

Dynamic analysis done to evaluate potential sources in piping systems will be done using the methods, loading combinations, and allowable stresses employed with safety related auxiliary piping qualified for the HOSGRI event. These methods and criteria are documented in Section 8 of the report entitled, "Seismic Evaluation for Postulated 7.5M Hosgri Earthquake" also known as the "HOSGRI Report" which was first filed as amendment 50 to the Diablo Canyon Nuclear Power Plant FSAR and updated in several subsequent amendments. Piping and tubing of 1" NPS and smaller size will not be analyzed nor assumed to rupture due to seismic inertial loads.

<u>TABLE 4-5-2</u>

<u>ASSUMED DISPLACEMENT OF PIPE</u>

| Nominal Pipe Size (inches) | Pipe Displacement (inches) |
|---|---|
| up to 1 1/2 | 24 |
| 2 | 20 |
| 3 | 18 |
| 4 | 16 |
| 6 | 14 |
| 8 | 14 |
| 10 | 12 |
| 12 | 12 |

For pipe greater than 12" NPS, deflections are considered as an unusual situation, Criterion PF9.

### 4.5.1.6 Instrumentation and Control, Source Evaluation

Capability of instrumentation and control equipment to physically interact with and inflict damage upon other power plant equipment is limited because of the size of the I&C equipment relative to potential targets. Interaction via seismically induced perturbation of signals from control equipment is discussed in section 4.6.2 The only two categories defined for direct physical interaction potential from I&C sources are discussed below.

IF1 - Failure of instrument extended proportions greater than 12" in length which exceed 50 lbs. total mass.

Most instruments are low in mass and insensitive to seismic inertial loads. In some cases, significant extended proportions exist for transmitters, air plenums, etc., but few such configurations are found in the plant. Class I instruments have been seismically qualified by tests which in many instances can be extended to Class II instruments. For the most part, few structural failures of instruments are expected.

IF2 - Extraordinary or unusual I&C situations not otherwise covered.

Any other structural failures of instruments such as support failures, large deflections, etc. will be treated as special situations.

### 4.5.2 Interaction Effects Evaluation Criteria

Once an interaction is identified as sufficiently credible to require more evaluation than can be done quickly from inspection, it must be resolved in an acceptable manner and the resolution documented. The interactions may be direct physical interactions as exemplified by the following categories:

Mechanical:

- impact from vibrating bodies
- impact from falling bodies
- pipe whip
- missiles

Electrical

- unwanted open circuit (loss of power control)
- unwanted closed circuit
- unwanted energization

Pneumatic

- loss of pressure (loss of control)
- unwanted pressurization
- jet impingement
- hostile gas

Hydraulic

- loss of pressure
  - (a) loss of control
  - (b) loss of lubrication
- unwanted pressurization
- jet impingement
- flooding
- hostile fluids

Environmental

- elevated temperatures
- steam
- radiation

The interactions may also be indirect as in the case where a source may fail in a manner such as to damage another piece of non-safety related equipment which then and only then could interact detrimentally with a target. Another category of indirect interaction involves inadvertant or degraded operation of equipment which may be induced by seismic effects even though no physical failure is credible. Such indirect interactions are also considered.

Interactions are evaluated for their impact on the required safety functions and redundancy of identified targets. The results of the evaluation will then determine the method of resolution. In order of preference, the following categories acceptable methods of resolution of identified interactions.

a. Target Operability Evaluation:

The first approach to resolution is to show that the target's safety function is not impaired. This may be accomplished by studying the means by which impairment occurs and the possible extent of the impairment. For example, a pneumatically operated valve may be required to close during shutdown, but falling equipment could sever the air line so air supply to the operator is lost. If the valve is a "fail open" type, then shutdown capability is compromised, but if the valve is a "failed closed" type, then shutdown capability is not compromised even though the air supply is lost. In this example it is also necessary to consider consequences of crimping the air line, as well as the effect of a lost air line.

This example is typical of the reasoning process that is necessary in the evaluation of each interaction. A substantial degree of engineering judgement is, of necessity, expected to be used. Decisions based on judgement, along with the rationale, are documented.

b. Source Behavior Evaluation:

The second approach to resolution is to perform a more careful evaluation of the source under seismic excitation. If tests, analysis, or applicable experience can be developed to demonstrate that the item in question is qualified to withstand the postulated 7.5 M HOSGRI event, the interaction can be declared resolved on the basis that it will not credibly occur. Tests and analyses will be done using the methods and critera employed for safety related equipment and documented in the "HOSGRI Report."

c. Modification

If resolution is not possible by analysis or by test, the Interaction Team will recommend physical modifications to prevent detrimental interaction. The range of possible modifications includes guard structures, protective covers, restraining structures, and seismic stops. The criterion is to prevent impairment of function. If a modification is necessary, the most appropriate method and design will be chosen.

d. Change of Procedures:

The last method of resolution is by reordering the operating procedures or defining alternate means of providing the required safety functions. This option, although an unlikely choice, is still a possible solution.

Except for those interactions that require complex analysis, presently though to be few, the evaluation and resolution of the postulated interaction will be made at the site by the Interaction Team. The evaluation and resolution methods are discussed below in more detail.

4.5.2.1 Evaluation of Direct Interaction Effects

Where evaluation is directed to showing that the safety function of a target is not impaired by an identified direct interaction, the following guidance has been established. For cases not covered, criteria are developed and documented to provide an analagous level of rigor to the guidance herein provided.

a. Direct impact of missiles or falling objects on structures and components can be evaluated using the criteria of sections 3.3.2 and 3.5 of the Diablo Canyon FSAR and in ANSI Standard N660, Plant Design Against Missiles. In cases of small low energy objects impacting large steel encased equipment it may be possible to show no damage by inspection. Care must be taken to consider such appurtanances as instruments, power connections, cooling and lubrication connections.

b. Direct impact of missiles or falling objects an HVAC ducts can be evaluated using the values in Table 4-5-3. If the maximum impact energy is less than the tabulated value of interact, no loss of function can be assumed.

c. Dynamic effects of breaks in piping can be evaluated using the criteria in section 3.6 of the Diablo Canyon FSAR. A very useful experimentally derived rule of thumb in connection with whipping or falling pipes is that smaller pipes do not rupture larger pipes by whipping into them.

d. Flooding effects of broken or leaking pipes are evaluated using the criteria of appendix 3.6A of the Diablo Canyon FSAR.

e. Environmental effects of broken or leaking piping, tanks, etc. are evaluated by comparison of the estimated environment with the target's qualification profile. Helpful criteria and data are contained in section 3.11 of the Diablo Canyon FSAR.

### 4.5.2.1 Evaluation of Indirect Interaction Effects

Two types of indirect interaction are considered; chain-reaction failures and inadvertant or degraded operation. For the chain-reaction events, the criteria for evaluation are the same as for the direct interactions. It must be remembered that each step in chain scenaris has an associated probability less than one and that judgement must be applied to eliminate very unlikely sequences. The other category is discussed in the following paragraphs.

The interactions described so far are physical, related by physical proximity, and identified by a walkdown team on site. Another type of interaction is one which causes an inadvertent operation or operational failure which affects the system function even though no obvious physical failures occur. An original design assumption was that all control systems that were not supplied with vital power would fail to the loss-of-power mode. Design provisions ensured that this would indeed occur. Therefore, if nonvital power (either air or electrical) is lost, the original design assumption is maintained. If, however, nonvital power is not lost, the possibility exists that the assumed failure will not occur and the unqualified control system will fail in a mode other than considered in the design. The following possibilities can be concluded for safety related devices and systems.

(a) If the device is air operated with spring opposition (e.g., pneumatic valves or pneumatic controllers), the design assumptions are correct if air is lost. If air is not lost and the device does not fail or fails in such a way as to vent air, the design assumptions are correct. If however, air is not lost and the device operates in an unpredictable manner, an adverse interaction would be conceivable.

(b) If the device is air operated with low level electrical signals (e.g., electro-pneumatic converters), the logic given in possibility (1) above applies in that loss of signal will cause failure to the proper mode and maintained signal would make failure dependent on the air supply. Low level "hot-shorts" are impossible since a low level signal cannot melt through a wrie. If a high level hot short occurred, it would demolish the unit input and cause a loss-of-signal failure.

(c) If the device is air operated and has electrical power (e.g., solenoid valves), the logic given in possibility (2) above applies except that hot shorts will be considered as a source of adverse interactions.

(d) If the device is totally electrically operated, loss of power (or signal) will support the design basis. Hot shorts are the only failures that could adversely affect the system function.

The procedure to evaluate possible interactions will involve all of the functions and flowpaths identified as needed to get to safe shutdown. All control loops which interface with those functions and flowpaths will be identified. For purposes of this review, the assumption is that flowpaths must be such that the pressure boundary integrity is maintained active components (e.g., pumps) must be capable of being operated and stopped. To maintain integrity, all valves in the path must capable of being closed. Alternatively, they must be capable of being opened or closed as required using either remote manual or accessible manual means. All control loops for devices which affect this requirement are reviewed.

Valves which must operate will only be given cursory review to ensure that all components are qualified since operability after a seismic event has already been considered in their design.

Valves with required failure modes will be reviewed to determine if any adverse interactions could occur. Valves which have no operability or failure requirements will not be reviewed in this portion of the program.

Operability of required pumps has previously been ensured, including seismic qualification of the control systems. In addition, the environmental effects of high energy line breaks, including jet impingement on the control systems, have previously been evaluated. These mechanisms are ways in which failing nonqualified equipment can interact with safe-shutdown equipment in a detrimental manner. The interactions envisioned are direct or primary interactions in the sense that the failing equipment interacts directly with the safe-shutdown equipment.

In the event that questionable indirect interactions are identified which are not readily evaluated to be acceptable with the above methods, the resolution then becomes one of modification such as redesign or replacement of the source equipment, rerouting or upgrading of control and electrical wiring.

## 4.6 Modification Criteria

Modifications may be required to resolve identified seismically induced systems interactions. These modifications may be any of the following:

a. Modification of the source to eliminate the adverse seismic behavior by bracing, supporting, or reinforcing the source equipment.

b. shielding or relocation of the target to intercept the physical interaction.

c. modification of the target to permit retention of the required safety function in spite of the interaction.

The criteria for structural or mechanical modifications are the same as documented for safety related structures and equipment in the HOSGRI Report.

For relocations or other non-structural/mechanical changes, the criterion for acceptability is that the modified situation, when reevaluated for interactions using the evaluation criteria previously stated, is considered resolved.

## 4.7 Documentation Categories

Each identified interaction will be documented as described in Chapter 5 using the interaction categories previously discussed. The resolution of each interaction will be documented using the following category codes:

R1 - No postulated interactions.

R2 - No standard resolution criteria exists. Calculations to be provided.

R3 - Interacting component to be modified to qualify seismically.

R4 - Interacting component supported identically to target component.

R5 - Interacting piping component inflicts insufficient target damage as follows:

Target pipe at least twice the nominal pipe size larger than the interacting pipe.

R6 - Interacting component inflicts insufficient target damage; calculations to be provided.

R7 - Potential interaction prevented by other components. Secondary interactions not precluded by this criteria.

R8 - Target is located a distance greater than the maximum interacting piping component deflection given in Table 4-5-2.

R9 - Deflection of interacting component prevented by design.

R10 - Potential interaction precluded due to geometry of the equipment layout.

R11 - Leakage insufficient in volume or velocity to compromise the target function or its associated area drain system.

R12 - Interacting component sufficiently distant from target to prevent interaction.

R13 - Target component environment change within acceptable limits.

R14 - Interacting component of insufficient kinetic energy to damage target.

R15 - Electrical power cable contact with target does not affect operability of target.

R16 - Seismic stops or restraints to be added to interacting component to prevent excessive deflections.

## TABLE 4-5-3

## ALLOWABLE KINETIC ENERGY VALUES FOR CLASS I DUCTS AS TARGETS

| Duct Size Diameter | Span 12" | 24" | 36" | 48" | 60" |
|---|---|---|---|---|---|
| 4" | 0.8 in-lb | 1.4 | 1.8 | 1.8 | 1.5 |
| 6 | 1.2 | 2.2 | 3.0 | 3.4 | 3.3 |
| 8 | 0.9 | 1.8 | 2.3 | 2.6 | 2.6 |
| 10 | 1.7 | 3.4 | 4.7 | 5.7 | 6.3 |
| 12 | 1.4 | 2.8 | 3.9 | 4.8 | 5.2 |
| 14 | 1.2 | 2.4 | 3.4 | 4.1 | 4.5 |
| 16 | 1.1 | 2.1 | 2.9 | 3.6 | 3.9 |
| 18 | 1.0 | 1.9 | 2.6 | 3.2 | 3.5 |
| 20 | 0.9 | 1.7 | 2.4 | 2.9 | 3.1 |
| 22 | 0.8 | 1.5 | 2.1 | 2.6 | 2.9 |
| 24 | 1.4 | 2.8 | 4.0 | 5.0 | 5.7 |
| 26 | 1.3 | 2.6 | 3.7 | 4.6 | 5.3 |
| 28 | 2.1 | 2.4 | 3.4 | 4.3 | 4.9 |
| 30 | 1.1 | 2.2 | 3.2 | 4.0 | 4.6 |
| 32 | 1.1 | 2.1 | 3.0 | 3.7 | 4.3 |
| 34 | 1.0 | 2.0 | 2.8 | 3.5 | 4.0 |
| 36 | 1.0 | 1.8 | 2.6 | 3.3 | 3.8 |
| 38 | 1.5 | 2.9 | 4.2 | 5.2 | 6.1 |
| 40 | 1.4 | 2.7 | 4.0 | 5.0 | 5.8 |
| 42 | 1.3 | 2.6 | 3.8 | 4.7 | 5.6 |
| 44 | 1.3 | 2.5 | 3.6 | 4.5 | 5.3 |
| 46 | 1.2 | 2.4 | 3.4 | 4.3 | 51. |
| 48 | 1.2 | 2.3 | 3.3 | 4.2 | 4.9 |
| 50 | 1.1 | 2.2 | 3.1 | 4.0 | 4.7 |
| 52 | 2.7 | 5.3 | 7.8 | 10.0 | 12.0 |
| 54 | 2.6 | 5.1 | 7.4 | 9.6 | 11.5 |
| 56 | 2.5 | 4.9 | 7.2 | 9.3 | 11.2 |
| 58 | 2.4 | 4.7 | 6.9 | 9.0 | 10.8 |
| 60 | 2.3 | 4.6 | 6.7 | 8.6 | 10.4 |

Note: An allowable bending stress of 10 ksi has been used in accordance with the SMACNA Code (Sheet Metal and Air Conditioning Contractors National Association, Inc.).

SYSTEMS INTERACTION PROGRAM

CHAPTER 5.0 - PROGRAM DESCRIPTION

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SYSTEMS INTERACTION PROGRAM

# CHAPTER 5.0 - PROGRAM DESCRIPTION

## 5.1 PURPOSE

This procedure identifies the general procedures to be followed by the walkdown team in planning, conducting, and reporting walkdowns in their respective disciplines.

## 5.2 SCOPE

This procedure includes:

a. General definition

b. Example forms for identifying those components to be evaluated as a source or target for postulated interactions.

c. Techniques to be used in performing the walkdown.

d. Example forms for reporting postulated failures, interactions and recommended resolutions.

## 5.3 DEFINITIONS

5.3.1 Component - An individual device in a subsystem. Examples are valves, tubing, wiring, switches, etc.

5.3.2 Safety Function - That action which must be available or performed to prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.

5.3.3 Interaction - An unintended contact (mechanical or electrical) between a target and a source item. A target item is a structure, system or component important to safety, as defined in 10CFR.50, Appendix A, General Design Criteria for Nuclear Power Plants; a source item is any structure, system or component which does not fall under this category. Henceforth, these will be referred to as target and source. In terms of relationship, a source is an item which affects a target. It is assumed that no target item as defined above will fail in a manner as to impact with another target item because the target items have been seismically qualified under other programs.

5.3.4 Subsystem - Those devices (control devices) which control a system, and other devices (i.e.: sensors and actuation devices) needed to control the control devices. For example, a valve and all its control devices are subsystem. The subsystem will be identified by the identification of the controlled device.

5.3.5 Standard Resolution Criteria - That resolution that can be reached in the field by Specific Resolution Criteria as described in Chapter 4.

5.3.6 System - The interconnected components and equipment which perform a safety function. A system will be defined as available if it is intact and operational. To be intact, the required flowpath must have no failures, the desired flowpath open, and the undesired flowpaths isolated. To be operational, a system must be controllable to the extent required by the operator. For example, all required pumps must be capable of being run or stopped, and all valves which must be operated must be capable of being operated as required. All indicators needed by the operator to operate the system must work.

## 5.4 PRE-WALKDOWN PLANNING

### 5.4.1 Safety-Related Functions and Systems Matrix

The first step is to identify the safety functions that must remain operative during an earthquake. If the safety functions are assured, the plant will be capable of preventing or mitigating the consequences of postulated accidents that could cause undue risk to the health and safety of the public.

The single active failure criterion will continue to be satisfied and the palnt can accept a LOCA, a high energy line break, or any of the other design basis faults.

Each safety function will be identified as being required for a specific safety purpose or purposes.

Following identification of each safety function will be a list of those applicable systems which are responsible for performing that function.

Most safety functions can be performed by more than one system. In such cases, all systems will be identified. The redundancy to compensate for single failures will be maintained.

All disciplines will be reviewd for each safety function to ensure that all of the associated systems have been included.

### 5.4.2 System Matrix

For each target system identified, a System Matrix will be completed, as shown in Table 5-1. In each System Matrix, all of the subsystems required for the operability of that system will be listed and numbered sequentially, by safety function and subsystem numbers.

The operating requirements for each subsystem will also be listed. In general, these will be statements like fail open, fail closed, operate (open and close), run, etc.

### 5.4.3 Subsystem Matrix

A subsystem Matrix, as shown in Table 5-2, will be completed for each subsystem listed in Table 5-1.

With required safety functions and related target systems identified, system-by-system review will be performed based on the work done for the Hosgri evaluation to determine all the components, instrumentation, and equipment necessary to ensure the safety functions required.

The Subsystem Matrix identifies each component and equipment required to ensure the operability of their associated target system.

Each item of equipment will be, in general, a part of a control circuit, a power circuit (electric or pneumatic), or a fluid flowpath.

Each of these circuits or flowpaths for each item will be examined separately and traced to its origin. Each item of equipment including the pathway (pipe or cable) will be considered and categorized in order to establish which equipment must be protected.

Each component in the Subsystem Matrix will be listed and numbered sequentially, by safety function, subsystem, and component numbers. A prefix identification will be that which is used to identify the device in the field.

For a cable in a cable tray or conduit, both the cable and tray identifications shall be used.

The safety class of the component and the fire area location of the component shall also be listed.

For components (e.g., cables) which involve more than one fire area, all applicable fire areas shall be listed.

Fire areas shall be listed by identification number.

## 5.5 WALKDOWN PROCEDURE

1. The Interdisciplinary Team begins a walkdown in a compartment within a fire zone as follows:

   Identify piping and equipment to be evaluated.

   Interactions will be evaluated using the criteria described in Chapter 4. These interaction will be evaluated as follows:

   a. first, from the standpoint of interaction sources, and

b. second, from the standpoint of interaction targets, whether safety grade or otherwise. In the instance of chain interactions only (e.g., a source impacts another source which, in turn impacts a target), a source may act like a target.

Walk down each pipeline or cable tray and evaluate each section for interactions. Evaluate each component and trace all associated power and instrumentation lines to the boundaries of the compartment.

Check off each system and component on the applicable matrix to ensure that evaluation was completed. Note areas where further tracing of power or instrumentation lines is required.

2. Each item of equipment involved in the safety function is successively considered together with its control and power circuit, whether pnuemetic or electric. When a particular item of equipment is found to be necessary to perform the safety function, the power and control circuits will be traced to their origins. All intermediate equipment will be assumed to be required equipment, (Table 5-2). This includes all equipment that must perform a safety function and, therefore, must be protected from detrimental interaction with the source equipment during an earthquake. The detrimental interactions may be mechanical, electrical, pneumatic, hydraulic, or environmental.

3. On the walkdown, it will be necessary to determine if a component in a fire area is subject to any of the following hazards.

   a. Direct physical contact by failure on source equipment.

   b. Jet impingement from failure of a source-type high energy line.

c. High temperature, pressure or humidity due to failure of source-type high energy lines.

d. Flood due to failure of source-type piping, causing a leak greater than the capacity of the drain system.

e. Any other hazards that become apparent.

4. Inspect each item to be evaluated in a given fire zone. Each source unit in the vicinity is postulated to fail or be displaced in various ways, causing different types and combinations of interactions.

Once a potential interaction is identified, it is documented on an Interaction Documentation Sheet (see Table 5-4).

Once a failure mode is assumed, determine whether or not that interaction poses a problem to the target equipment, by determining whether or not the source equipment can be seismically qualified.

Because there is a large number of sources for interactions, the tactic will be to identify generic types of interactions and evaluate those. For example, if a line is under a maze of source equipment, that should be so noted. If the line is high energy line, then temperature, pressure, and radiation are potential problems.

Unless a fire area is very large, it is anticipated that each column will look the same for all components. There will be differentiations only if the area is large enough so that a failure in one location of the area could not cause an interaction in another location.

The intent here is to provide indications of problems and their extent. It will probably not be feasible to give postulated environments at this time.

Identify and document interactions per Paragraph 5.6 below and by completing the Data Base Forms (Table 5-3).

Resolve interaction immediately (on site) or defer interaction resolution for future analysis. Document rationale used for resolutions arrived at by engineering judgment.

Repeat the above for all compartments within a particular fire zone and for all fire zones.

## 5.6 DOCUMENTATION

### 5.6.1 Data Base (Table 5-3)

As the walkdown progresses, the Data Base forms of Table 5-3 shall be filled out in each fire zone for each discipline.

### 5.6.2 Subsystem Matrix (Table 5-2)

The failure mode without power should be obvious, and it can be completed for each component.

For the failure mode with power, if the component is qualified and has no indications, the answer is "none."

If there is an indication or the device is not qualified, the failure mode must be determined. If it cannot be determined, it must be listed as "worst possible."

### 5.6.3 System Matrix (Table 5-1)

After the subsystem matrix is completed, the failure mode of the subsystem is determined for the nonpower and power conditions. These are both put on the system matrix and compared with the desired operability requirements.

Again, "worst possible" is a legitimate failure mode.

If the derivation of a failure mode for a subsystem is not obvious from the subsystem matrix, a reference to an analysis or explanation shall be given.

## 5.7 REVIEW AND ANALYSES

After the safety functions have been identified, it must be decided if the safety function will be available.

If a function is not available at this stage of review, the first step is to attempt to remove the offending interactions by generic analysis.

Potential interactions will fall into one of the following categories:

a. The credibility of the interaction occurring is such that it is of no concern, or

b. The credibility of the interaction occurring is of concern. Therefore:

   (1) The results of the interaction are inconsequential, or

   (2) The results of the interaction are consequential; therefore, one or more of the following may be required.

(a) Target reinforcement

(b) Source reinforcement

(c) Shielding between target and source

The seismic qualification of source components, equipment, and structures by analysis is a first possible step in resolving adverse interactions.

Those items which cannot be reasonably qualified by analysis will be qualified by other methods such as testing, past seismic performance which is carefully documented and determined to be applicable, or engineering judgment.

Finally, seismic induced failure of source items will be assumed, and the impact of such failure on safety function capability will be assessed by an onsite inspection which considers failure modes and effects as well as the location of the item assumed to fail, relative to components or systems required for safety functions.

Any modifications deemed necessary will be defined.

TABLE 5-1

SYSTEM MATRIX

Page ____ of ____

Matrix No. ____________ Function ____________ System ____________

| No. | Subsystem | Desired Operability Requirements | Failure Mode With Power | Failure Mode Without Power | Comments |
|---|---|---|---|---|---|

## TABLE 5-2

## SUBSYSTEM MATRIX

Page ___ of ___

Matrix No. ______________________________ Subsystem No. __________________________

| Component | Identification | Location Matrix | Safety Class | Failure Mode With Power | Failure Mode Without Power | Notes |
|---|---|---|---|---|---|---|

TABLE 5-3

COMPUTERIZED DATA BASE

## 1.0 PURPOSE

These entry forms attached are completed for the purpose of recording both walkdown findings and the status of any action which is taken as a result of these findings.

Specific forms and guidelines for their completion are provided to facilitate direct computer entry and retrieval of this data.

## 2.0 APPLICABILITY

All findings made on the walkdown will be recorded on a Records Management System (RMS) coding form. The information from these coding forms will be executed into a computer.

## 3.0 PROCEDURE

3.1 A System Interaction Program Data Entry Form is to be completed for each unique matrix number. The System Interaction Program Data Entry Continuation Form is to be used when more space is needed.

3.2 The appropriate dictionary is to be used to select terms to enter in the boxes provided. At the beginning of each category, the specific dictionary is listed for reference.

a. New terms which are not in the appropriate dictionary may be entered in the boxes when they meet the guidelines for the kind of information to be entered in that category.

b. New terms are to be circled on the entry form.

c. Place two commas between each term, and use the continuation sheet when enough space is not provided on the form.

TABLE 5-3 (Cont.)

RECORDS MANAGEMENT SYSTEM
DOCUMENT INDEX CODING FORM D

TABLE 5-3 (Cont.)

Form #S-1

SYSTEM INTERACTION DATA ENTRY FORM
CRITERIA RESPONSE SHEET
FOR DSCR CATEGORY

GUIDELINES FOR USE OF THIS SHEET:

Use this sheet to record the response to each criteria in the DSCR category. Enter the response immediately following the criteria number. Only one of three possible responses may be entered:

Y for YES
N for NO
X to indicate that the criteria does not apply

CATEGORY
DSCR 7

| CRITERIA NO | CRITERIA NO | CRITERIA NO | CRITERIA NO | CRITERIA NO |
|---|---|---|---|---|
| PF1__ | MF1__ | EF1__ | RF1__ | R1____ |
| PF2__ | MF2__ | EF2__ | RF2__ | R2____ |
| PF3__ | MF3__ | EF3__ | RF3__ | R3____ |
| PF4__ | MF4__ | EF4__ | RF4__ | R4____ |
| PF5__ | MF5__ | | | R5____ |
| PF6__ | MF6__ | | | R6____ |
| PF7__ | | | | R7____ |
| PF8__ | | | | R8____ |
| PF9__ | | | | R9____ |
| | | | | R10___ |
| | | | | R11___ |
| | | | | R12___ |
| | | | | R13___ |
| | | | | R14___ |
| | | | | R15___ |
| | | | | R16___ |

| CRITERIA NO | CRITERIA NO | CRITERIA NO |
|---|---|---|
| HF1__ | CF1__ | IF1__ |
| HF2__ | CF2__ | IF2__ |
| HF3__ | CF3__ | |
| HF4__ | CF4__ | |
| HF5__ | CF5__ | |

[illegible]

TABLE 5-4

PACIFIC GAS & ELECTRIC CO.
DIABLO CANYON PLANT
SEISMICALLY INDUCED SYSTEMS INTERACTION PROGRAM
INTERACTION DOCUMENTATION SHEET
(Use additional sheets if required)

Fire Zone:

Location within Fire Zone:

Postulated Interaction No.:

Identification of interacting components
including operating mode/position, etc.:

Description of Postulated Interaction:

Recommended Resolution of Postulated Interaction:

Final Resolution of Postulated Interaction:

Originator/Date

Reviewer/Date